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Bulk Solids Handling Research at the University of the Witwatersrand, Johannesburg, South Africa

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1. Introduction

The Materials Handling Research Unit of the University of the Witwatersrand has since 1972 been active in a wide range of bulk solids handling activities.

From its formative years as a research programme instituted to conduct work in specific areas of pneumatic conveying, the Unit now conducts research work in areas covering:

- Pneumatic Conveying (All modes — dilute, medium & dense-phase; vacuum and pressure conveying)
- Hydraulic Conveying (dilute and paste conveying)
- Pneumo Capsule Conveying
- Aspects of Belt Conveying
- Storage and discharge of bulk materials from bins and hoppers.

Within each of the above categories, researchers carry out work covering both the fundamental method and applied aspects of bulk solids handling.

2. Experimental Philosophy

After extensive literature surveys it was evident that in order to conduct meaningful research in the field of bulk solids handling, it would be necessary to carry out experimental work on realistically sized test rigs. As such, the basic experimental philosophy adopted by the Unit is:

> *Where possible all experimental work is conducted on full size test rigs in which the actual system is simulated in all respects. Only when reliable scaling of procedures are available is work conducted on a reduced size experimental apparatus.*

This philosophy has received widespread approval from South African industry and has afforded researchers an opportunity of gaining excellent experience in many industrial situations.

Currently, about 70 % of the projects undertaken by the Unit result in the installation of a system in industry.

3. Function of Unit

The Unit is a formal part of the School of Mechanical Engineering and has strong academic links with its home department. In addition to employing a compliment of fulltime researchers backed up by the necessary administrative and technical staff, the Unit has many undergraduate and postgraduate students working on various projects.

Duration of projects can range from several days up to a year. The majority of projects are sponsored by industrial organisations and consequently have a bias towards applied research. However, support from both the University and State bodies facilitate the opportunity to carry out some fundamental research studies.

4. Laboratory Facilities

The Unit is housed on an extensive tract of land about 20 km to the North of Johannesburg. Laboratory buildings (Fig. 1) include a dedicated bulk solids laboratory, a compressor house and a workshop and vehicle laboratory. The buildings represent some 5,000 m² under cover.

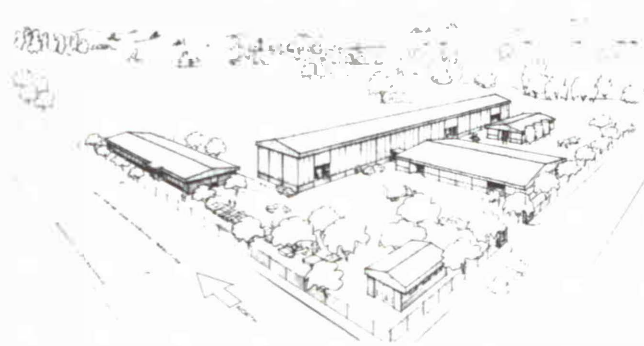

Fig. 1: The Research Laboratories of the Materials Handling Research Group

The laboratory has been located in an area where expansion is virtually unlimited. As such, it is possible to conduct research on pipelines which are in excess of 2,000 m long. There is a total installed electrical power of 2 MW of which 1,000 kW is taken up by compressed air power for pneumatic conveying research.

In addition to the basic materials handling equipment, the laboratory has all the necessary back-up services required for bulk solids handling. A full particle sizing and screening facility, coupled with drying equipment and associated handling equipment is available.

Specialist instrumentation includes a laser doppler anemometer, on-line data acquisition facilities for monitoring up to 20,000 inputs per second, all the necessary transducers for flow, pressure and temperature measurement.

5. Current Bulk Solids Research Programmes

At present, bulk solids research activities are mainly concentrated on mining applications. In particular there is much interest in South Africa in backfilling of both coal and gold mines.

Backfilling research is directed towards transportation of waste materials to the underground workings as well as the effective placement of the fill to achieve a stable support. In the gold mines, by virtue of mining to depths in excess of 3,000 metres, backfill is required to minimise rockbursts which frequently occur due to the high stresses resulting from deep level mining.

Backfilling in the coal mines is required both as a means of disposal of fly ash and also as a means of improving the extraction efficiency from bord and pillar coal mines. South African coal has a high ash content and a typical thermal power station can produce up to 10,000 tonnes of fly ash per 24 hour day.

5.1 Pneumatic Conveying Research

Current Pneumatic conveying activities are concerned with:

5.1.1 Fundamental Dilute Phase Pneumatic Conveying — In an attempt to build up a theoretical model for dilute phase pneumatic conveying a special test rig has been constructed. The rig has been designed to facilitate the collection of basic information and can be varied to provide information on such aspects as bends, pipe and particle diameter, velocity and concentration profiles.

Work in drag reducing flows has resulted in the Unit being awarded several patents. It has been found [1] that by the introduction of pulsation into the air flow (Fig. 2) a 'before' and 'after' situation can be effected, in which either drag reduction (pulsatile flow) or drag increase (non-pulsatile flow) will be present. Drag reduction being defined as that situation which occurs when a *gas-solid suspension* is transported at a *lower* pressure drop than that which would be generated by the gas component alone.

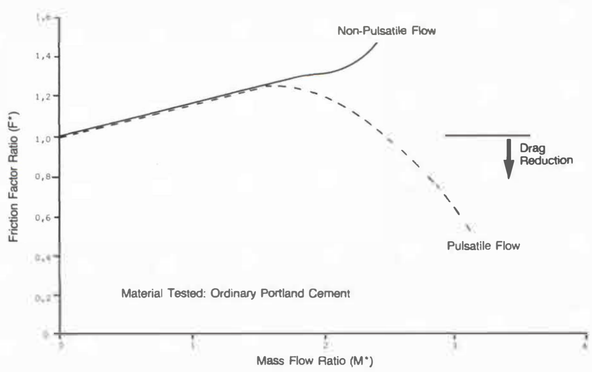

Fig. 2: Graph showing system performance in pulsatile and non-pulsatile flow

Tests on the influence of the method of feeding the solids into the pipeline have produced the most significant results to date. It has been shown (Fig. 3), that when using a rotary valve as a feeding device for fine fluidisable powders, significant savings in power consumption can be effected if the solids are introduced as smoothly as possible. Thus by increasing the speed of rotation of the valve a reduction in power consumption is effected. These results indicate the desirability of fitting rotary valves with a spiral rotor.

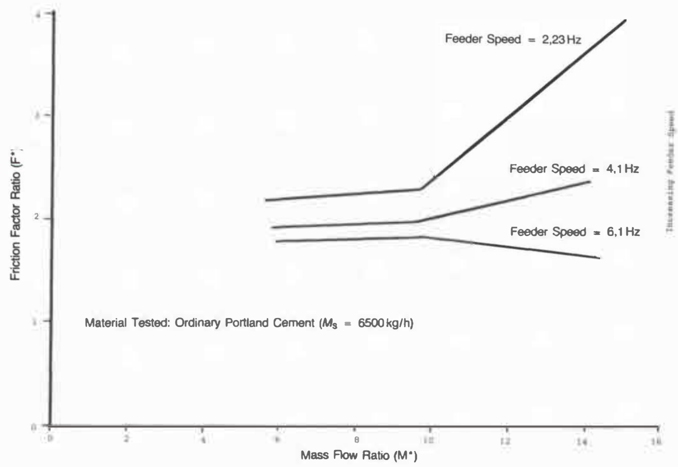

Fig. 3: Graph showing the influence of feeder speed on system performance

5.1.2 Dense Phase Conveying — Dense phase conveying research has been directed towards the use of bottom discharge blow vessels (Fig. 4) to transport a wide variety of products. In all the studies attempts have been made to maximise the performance of these systems.

Extensive use is made of Geldarts classification as a first attempt to identify the mode of conveying best suited to the product. Also every effort has been made to dispel the misnomer of dense phase conveying being synonymous with a blow vessel.

Perhaps the more significant results obtained from the research work to date has been on the influence of initial vessel pressure, (pressure to which the vessel is subjected to before opening the discharge valve), charging fraction (the ratio of the amount of material loaded into the vessel to the volumetric capacity of the vessel) and line length on system performance. Typical results [2] for fine fluidisable products (Fig. 5) indicate that it is desirable to have the vessel as full as possible, and to pressurise the vessel to pressures of the order of 450 kPa. These results are contrary to many preconceived notions of small blow vessels and pressure limitations of 300 kPa for a blow vessel.

Tests on the influence of an air receiver in the line also indicate that there is a possibility of using a 'smaller' capacity compressor in a batch operation blow vessel system.

5.1.3 Long Distance Pneumatic Conveying — With the development of the dosage valve system (Fig. 6) [3] two experi-

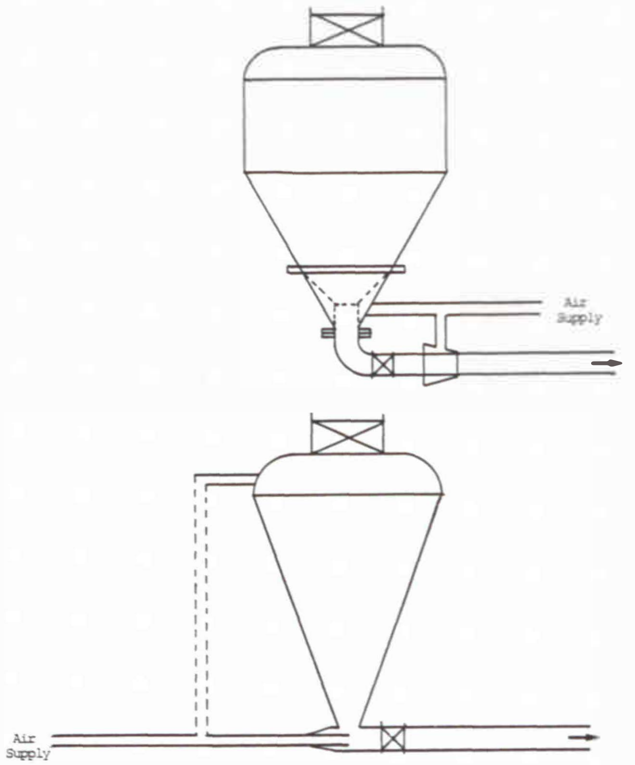

Fig. 4: Bottom discharge blow vessel with entrainment nozzle

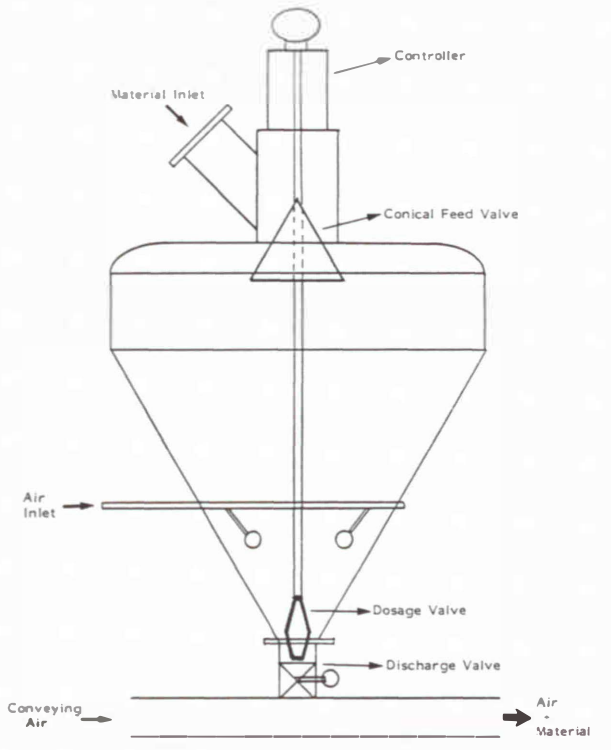

Fig. 6: Arrangement of dosage valve

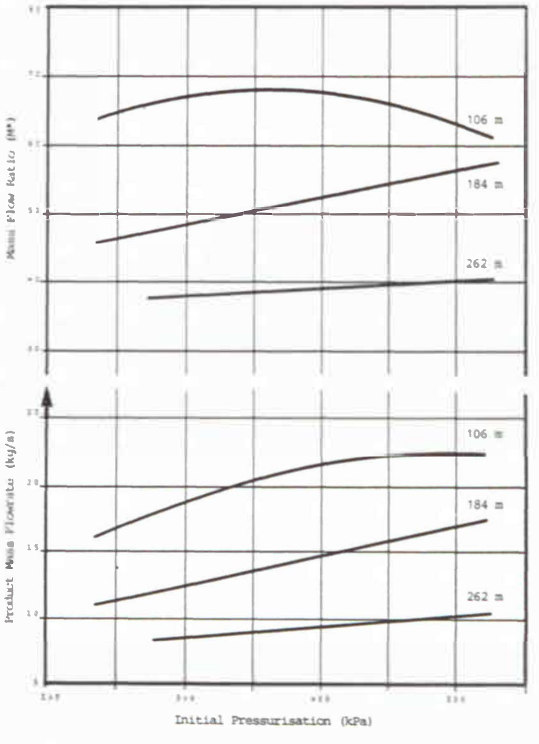

Fig. 5: Influence of initial pressurisation on product mass flowrate and mass flow ratio
(Charging Fraction 75 %, Air Flowrate 11 m^3/min FAD)

mental test rigs have been constructed to pneumatically transport dried gold slimes and fly ash over distances of 2,000 metres.

One test site (Fig. 7) is located on a slimes dump at a gold mine so that a fresh supply of material is constantly available for testing. The prime function of this test rig is to establish the operating criteria with a view to pneumatically transporting the slimes from the surface back underground.

The dosage valve system has a pneumatic sensing device which critically monitors the amount of material which is fed into the pipeline. As such the system can be 'tuned' to operate at maximum efficiency. Insipient blocking is instantaneously sensed and complete blockage is averted.

5.1.4 Large Particle Conveying — Initial trials [4] into the backfilling of gold mines using waste quartz rock up to 80 mm in size were abandoned due to severe wear on the rotary feeder, wear in pipes and the generation of high dust counts underground. One positive aspect of these trials was the attainment of compaction densities of up to 80 % of the in situ rock.

The good compaction densities was sufficient encouragement for a local mining company to sponsor a research programme to develop a suitable feeder. Much work has been conducted into the design and testing of a feeder. Trials to date have indicated that the new feeder (which contains no rotating parts) is proving most successful.

Currently an extensive programme is being launched into determining the wear mechanisms which take place in such large particle transport systems. In particular, a joint venture between the Materials Handling Research Unit and the Nuclear Physics Research Unit has been launched to investigate the use of thin layer activation (TLA) as a method of pipeline wear monitoring. This technique will facilitate 'dynamic' wear monitoring and thereby provide some insight into the wear process.

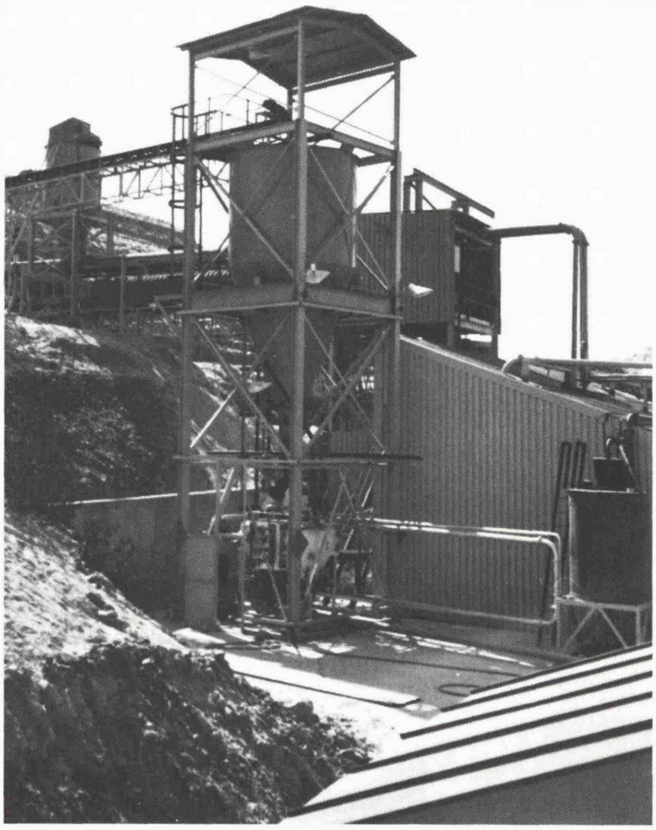

Fig. 7: View of feeding system for pneumatic conveying of dried gold slimes over 2,000 m for backfilling of gold mines

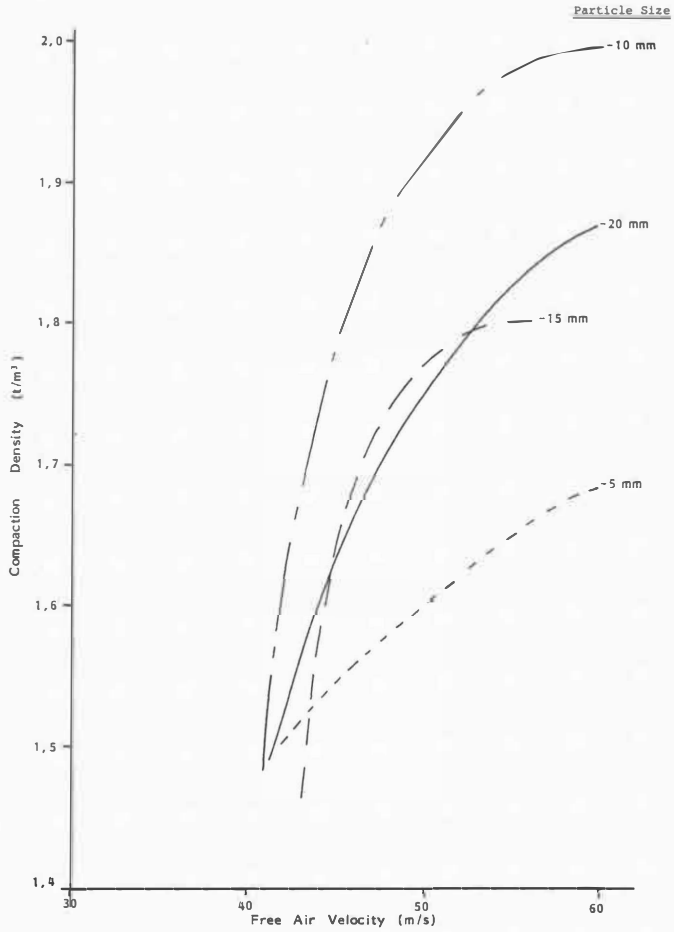

Fig. 8: Compaction density for pneumatic stowing

Simultaneously with the nuclear monitoring programme, wear studies are being conducted from a materials viewpoint as well. In addition to investigating the potential of Ion implantation techniques, research is being conducted by the Department of Metallurgy into the micro-structure of materials subjected to both impact and corrosive wear conditions.

In tests conducted [5] on the effectiveness of various particle sizes on compaction density, it has been found (Fig. 8) that an optimum conveying velocity (air) of the order of 60 m/s provides the most suitable fill.

5.2 Hydraulic Conveying Research Programme

The hydraulic conveying research programme covers both 'paste' conveying and dilute slurries. Paste transportation systems currently under investigation utilise positive displacement piston pumps as the prime mover. The test facility (Fig. 9) for these investigations provides for the testing of the pastes over distances of 900 metres. Pumping capable of producing pressure heads of 100 bar and flow rates of 45 m³/h of pastes are used in these investigations.

The dilute slurry programme is concerned with the total system performance. As such, not only is the performance of the slurry in the pipeline investigated, but also, the performance of the pump, valves, pipeline etc. is monitored. Thus it is possible to provide the potential user with information pertaining to the performance of the hardware as well.

At present, efforts are being concentrated on the transport of fly ash for both disposal purposes and backfilling of mines.

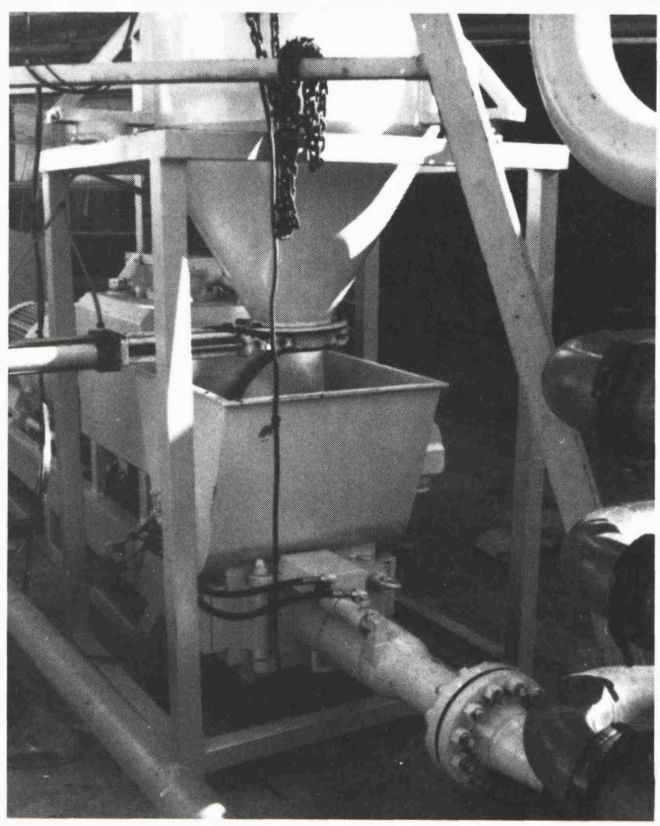

Fig. 9: View of positive displacement pumping system for long distance transportation of pastes

5.3 Pneumo Capsule Conveying Programme

An extensive research and development programme into pneumo capsule conveying is currently being undertaken by the Research Unit.

The prime objectives of this programme are to develop a total computer simulation programme for system design and evaluation as well as the construction of a large size test rig.

The computer simulation studies are almost complete. It is now possible to carry out a detailed assessment of a total pneumo capsule transportation system taking into consideration the topographical details of the terrain as well as all the other basic features such as throughput, etc.

Feasibility studies [6] undertaken for a variety of transportation requirements have indicated that in many situations the pneumo capsule system provides the most attractive alternative.

Based on these studies the Unit has received financial support to install a 2,000 metre long pipeline. Fibre cement pipes (300 mm in diameter) will be used for the system which will be capable of transporting products at the rate of 54 m^3/h. Provision has been made for a fully automatic loading and unloading station.

Capsules consist of wheeled bogies located at either end of a body made from a composite steel and fibreglass pipe.

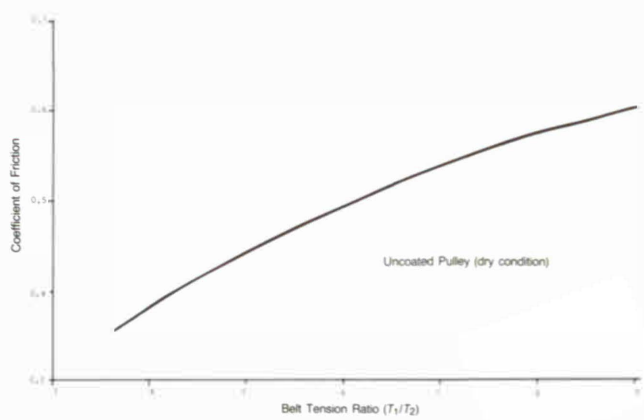

Fig. 10: Graph showing variation of coefficient of friction with belt tension ratio

5.4 Belt Conveying Research Programme

Research into belt conveyors is a recent addition to the Unit's activities in bulk solids handling research.

At present three projects are being investigated:

a) Belt conveyor design
b) Determination of the coefficient of friction for various pulley liners
c) Pulley design.

The design programme has been orientated towards the writing of a computer programme to aid the belt conveyor designer. The programme has been based on the CEMA [7] hand book. An added feature of this programme is the development of a simulation programme which, when complete, will enhance the design programme.

The initial phases of the research into the determination of coefficient of friction for pulley liners has been completed [8].

During the inital studies, an attempt has been made to design a suitable static and dynamic test rig. The eventual aim will be to find a correlation between the static and dynamic conditions such that it will be possible to carry out all future tests on a simple dynamic test rig. Initial results (Fig. 10) obtained from the static test rig indicate that the commonly accepted value of coefficient of friction might be optimistic. At present attention is being focussed on the construction of a loading arrangement for the dynamic test rig.

Work on pulley design is being carried out from a theoretical viewpoint and is in the elementary stages of development.

It is proposed to construct a recirculating belt conveyor test rig which will consist of two 1,200 mm wide conveyors 50 metres long. The test facility will be designed to facilitate research on virtually every aspect of belt conveyor design.

6. Conclusions

An attempt has been made to highlight some of the research work into bulk solids handling being investigated by the Materials Handling Research Unit. It is clear that in many areas much work still has to be done.

References

[1] Marcus, R.D., "An Investigation into the Influences of Pressure Pulsations on the Flow Characteristics of Solid Gaseous Suspensions", Ph.D. Thesis, School of Mechanical Engineering. University of the Witwatersrand, Johannesburg, Jan. 1978.

[2] Lohrmann, P.C. and Marcus, R.D., "The Influence of Velocity, Pressure and Line Length on the Performance of a Blow Vessel", Proceedings Pneumtech I, International Conference on Pneumatic Conveying Technology, Powder Advisory Centre, England, May 1982.

[3] Cuerten, H.J., "Long Distance Pneumatic Conveying", Proc. Int. Conf. on Materials Handling, SAIMechE, SAIMatlHdlg, University Wits, South Africa, Sept. 1981

[4] Marcus, R.D., Burgess, H., Fenderico, D.M., Fritella, A. and Vogel, R. "The Application of Pneumatic Conveying Techniques to the Mining Industry", Paper H2, Proc. 5th Int. Conf. on the Pneumatic Transport of Solids in Pipes, BHRA Fluid Engng, Cranfield, Bedford, UK, pp. 363—388, April 1980.

[5] Marcus, R.D. and Lohrmann, P.C., "The Application of Pneumatic Conveying in the Mining Industry II; with special reference to Large Particle Conveying", Proceedings Pneumatech I; International Conference on Pneumatic Conveying Technology, Powder Advisory Centre, England, May 1982.

[6] Swerdlow, P.C., "Feasibility Studies for Pneumo Capsule Systems", International Reports, Materials Handling Research Unit, University of the Witwatersrand, Johannesburg.

[7] Conveyor Equipment Manufacturers Association: "Belt Conveyors for Bulk Materials", 2nd Ed. ISBN 0-8436-1008-5.

[8] Hailes, D.J., Leask, G.M and Manneschijn, A., "Conveyor Belt Slip Over Drive Pulley", Final Year Research Project, School of Mechanical Engineering, University of the Witwatersrand, Johannesburg. November, 1982.